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Policy and Forecasting Models for the Chinese, South Korean, Australian, and European Union Meat Sectors

Abstract

Recent strong growth in the export of U.S. meat products combined with increasing Asian demand for feed grains has focused attention on tools to analyze growth potential in these markets. This paper demonstrates that structural models of the livestock industries in foreign countries can provide information about the prospects for meat and related agricultural commodities. They can also be used to analyze the impact of policy changes.

Disciplines

Agricultural and Resource Economics | Agricultural Economics | Econometrics | International Economics

Policy and Forecasting Models for the Chinese, South Korean, Australian, and European Union Meat Sectors

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POLICY AND FORECASTING MODELS FOR THE CHINESE, SOUTH KOREAN, AUSTRALIAN, AND EUROPEAN UNION MEAT SECTORS

Introduction

Strong growth in the export of U.S. meat products in recent years, combined with increasing demand in Asia for feed grains to supply expanding livestock industries in that region, has focused attention on tools to analyze the potential for growth in these markets. One common means of addressing some of these needs is to build structural models of these countries' livestock industries that can be used to provide information about the prospects for meat and related agricultural commodities, as well as analyze the impact of likely policy change. It is that interest that led to the respecification of structural models of the Chinese, South Korean, Australian and European Union (EU) meat sectors, the subject of this report.

Developments in both China and South Korea are already having an impact on the export of U.S. agricultural commodities and the prospects in both markets look bright. In South Korea, the more liberal trade policies agreed under the recent GATT outcome are no doubt having a positive influence, while current trends in China's imports of meat and grains coupled with its commitment to APEC to become an open market by 2020, all bode well for future trade.

The future of livestock industries in Australia and the EU will also play an important role in the outlook for U.S. livestock industries. Since the beef market was liberalized in 1991, Australia has remained the United States's major competitor in Japan, the single largest beef export market for both countries. The United States and Australia are also competing for market share in South Korea, the second largest export market for U.S. beef. As meat demand in these and other Asian markets continues to increase with further growth in consumer incomes, competition between U.S. and Australian beef is likely to intensify.

With the EU recently achieving freedom from foot and mouth disease status under the concept of “regionalisation,” the former sanitary restrictions that hindered EU beef exports to high-priced Asian markets like Japan and South Korea, have effectively been removed. Nevertheless, the ability of the EU to compete with alternative meat suppliers in Asian markets will in large part depend on EU’s ability to supply at competitive prices.

Revising FAPRI’s current livestock model by incorporating Korea and respecifying the structural representation of Australia and China, together with a more appropriate link between livestock production and feed demand, should contribute substantially to the performance of the FAPRI modeling system (see Devadoss et al. 1993). Also, the demand system of the European Union was revisited in view of required data updates as well as some possible weaknesses in the current estimates.

We first outline the underlying structure of the new livestock models and provide estimates of the important elasticities in the models. These parameters “summarize” the models most conveniently, and are the relevant explanators of the results of policy experiments and shocks.

Overview

Features of the Models and Development Philosophy

In keeping with the suite of FAPRI models, the new livestock components are annual and dynamic nonspatial, partial equilibrium models. They contain representations, typically nonlinear, of demand, supply, trade, and domestic market clearing price determination for up to four meat commodities—beef, pork, poultry, and sheep meat (lamb plus mutton)—and eggs in China. A summary of the models is presented here.

Summary of Commodity-Country Coverage

Domestic Supplies

- Production of beef, pork, and poultry in Australia.
- Production of beef, pork, poultry, sheep meat, and eggs in China.
- Production of beef, pork, and poultry in South Korea.

Domestic Demands

- Demand for beef, pork, poultry, and sheep meat in Australia.
- Demand for beef, pork, poultry, sheep meat, and eggs in China.

- Demand for beef, pork, and poultry in South Korea.
- Demand for beef, pork, poultry, and sheep meat in the European Union.
- Trade Demands
 - Beef export demand for Australia.
 - Pork, poultry, and egg export demands for China.
 - Poultry import demand for China.
 - Beef, pork, and poultry import demands for South Korea.
- Price Determination
 - Retail and producer market prices for beef, pork, and poultry in Australia.
 - Retail market prices for beef, pork, poultry, sheep meat, and eggs in China.
 - Retail and producer market prices for beef and pork in South Korea.
 - Wholesale and producer market prices for poultry in South Korea.

Some of the more important features include the modeling of meat demands as a two-stage budgeting process that at the lowest level, makes allowance for dynamic behavior in consumption. A simple partial adjustment form of dynamic consumer behavior was incorporated within these demand systems based on the approach developed by Ball, Beare, and Harris (1989). It is arguable that the simplicity of the partial adjustment demand system and the desire for parameter parsimony make this approach very appealing for empirical applications, especially in larger structural models.

In general, the dynamic behavior inherent in livestock supply response is also represented by a simple partial adjustment process. However, in the case of pork in China, production is modeled in a system of behavioral equations and pig inventory and production identities.

The more significant trade flows are also represented by separate behavioral relationships in the models. Typically, importers and exporters are assumed to adjust trade according to movements in prices and the extent to which domestic and traded meat commodities substitute for one another. For example, imports of beef, pork, and poultry by South Korea and beef exports from Australia are all assumed to vary with changes in the relative price of the domestic product and the exchange rate adjusted price of the similar internationally traded product.

Individual modeling of import and export trade flows also facilitates the incorporation in the models of the restrictions and other conditions imposed on trade as a result of government policy. Use of trade policy or price support mechanisms can lead to a large divergence between the domestic and internationally traded prices of similar meat products. For example, in 1994 in

South Korea where beef imports are controlled by government quotas, tariffs and mark-ups, the producer price of native cattle averaged around \$329/cwt while in the same year the Nebraska direct steer price averaged just under \$69/cwt.

Perhaps of more importance, the trade equations form the link between developments in the meat industries in each country because changes in trade affect the domestic price of each meat through the market clearing identities. In the China model, for example, the retail price of poultry adjusts until total supplies, which comprise domestic production and imports, equals domestic consumption plus exports of poultry. The process is presented in Figure 1. The exception to this paradigm is for the determination of the poultry price in Australia. It is obtained from an inverted supply equation, which is assumed to be perfectly elastic and is specified simply as a function of the price of domestic feedstuffs.

In constructing the country models reported here, behavioral equations are formulated from a manner consistent with economic theory, so that demand and supply equations are homogeneous of degree zero, parameters associated with price variables are appropriately signed, and implied elasticities are within an acceptable range. For the demand systems, symmetry and adding-up restrictions were also imposed. This reflects the fact that the models are used more frequently for policy impact analysis where the elasticities are critical to model outcomes.

The models comprise groups of behavioral equations, livestock inventory and production accounting identities, as well as several market clearing identities. While regression analysis was used to estimate most parameters in the behavioral equations, in a few instances this approach was not adopted for a number of reasons. For example, it quickly became apparent that attempts to estimate a partial adjustment specification for beef production in Australia and South Korea would fail to capture the complex dynamics of the supply response in those industries. In other cases, parameters could not be estimated with regression techniques simply because of a prohibitively small sample size or because it was considered inappropriate.

In such cases, “synthetic” behavioral equations were specified in which the price elasticities were imposed. The elasticities used in these synthetic equations were either obtained from estimates published in other studies or based on the authors’ judgment. A detailed technical

documentation of each country model, which includes equation specification, regression results, and within-sample forecasting diagnostics for a dynamic simulation is provided in the Appendix.

The functional forms selected for the behavioral equations are either linear or “linear in logs.” An important consideration in the choice of the functional form used in each model was the maturity or stage of development of the meat industry in each country. In the Australian and South Korean models, for instance, imposing constant elasticity relationships by employing “linear in log” specifications was assumed not to be too restrictive. In contrast, linear specifications were typically employed for the China model because it is more reasonable to expect the elasticities to change over time as quantities and prices vary. Both types of functional forms are used for the synthetic equations.

While the majority of stochastic equations were estimated by ordinary least squares (OLS) regression, for domestic retail meat demand components either Deaton and Muellbauer’s (1980) Almost Ideal Demand System or Moschini and Vissa’s Linear Inverse Demand System (1992) were estimated with the ITSUR technique in SAS[®]. A simple partial adjustment form of dynamic consumer behavior was incorporated within these demand systems based on the approach developed by Ball, Beare, and Harris (1989). It is arguable that the simplicity of the partial adjustment demand system and the desire for parameter parsimony make this approach very appealing for empirical applications, especially in larger structural models.

The annual data used for estimation include livestock inventories and meat production, consumption, trade, and stocks obtained from the PS&D data base of the United States Department of Agriculture’s Foreign Agriculture Service (USDA/FAS). Macroeconomic data for consumption expenditure, national income, consumer price indexes, and population was obtained from the International Monetary Fund (IMF) while specific organizations and statistical agencies in each country were the data sources for domestic meat and egg prices. The publications used for these data included the *Statistical Yearbook of China* (1994), the Australian Bureau of Agricultural and Resource Economics (ABARE) (1995), and *Materials on Price, Demand and Supply of Livestock Products* published by the National Livestock Co-operatives Federation in Seoul. The main source of price data for the European Union was the Meat and Livestock

Commission (1995), although additional price data were obtained from the national statistical agencies of EU member countries.

The size of the data sample used to estimate the stochastic equations varied among the countries. The largest sample was for Australia and South Korea, where data were available from 1965 to 1994. However, lack of price data restricted estimation of the EU demand system for 1975 to 1994. Although Chinese data were available for earlier years the estimation period was restricted to commence in 1978, the year in which the economic reform programs began. While livestock inventory, supply, utilization, and most price data were available for 1978 to 1994, the absence of retail prices for poultry before 1984 further limited the size of the sample used to estimate the demand system in China.

More detailed discussion of the modeling approach employed to represent supply, domestic demand, and the trade components of the models, together with estimates of the more important elasticities, are presented below.

Meat Supply Response

Generally, the models have a fairly simple representation of supply response for the meat industries in Australia, South Korea, and China. With the exception of chicken supply in Australia and pork production in China, the supply of meats and eggs is modeled in a Nerlovian partial adjustment framework. This framework is parsimonious in the number of estimated parameters and data requirements. In addition, representing supply with one equation rather than a system of equations greatly reduces the complexity and physical size of the model. It also lends itself to synthetic supply representations where supply elasticities, both short and long run, that are obtained from other sources rather than by direct estimation can be imposed on the model.

Typically in the partial adjustment framework, production is specified as a function of its own output price, input prices, and lagged production, with the lagged production attempting to capture the dynamics of the supply response. The size of the parameter on the lagged production variable determines not only the rate of adjustment, but also the size of the long-run impact of a change either in its own price or the price of inputs. In livestock industries, of course, it is the biological constraints on production that can result in large differences between the initial

response to a price change and the long-run impact, which in the case of the beef industry can be many years. Where production is joint, as is the case in the production of sheep meat and wool in China, a real return variable was constructed as a simple weighted average of the prices of the joint products. The weights used were the average wool cut and slaughter weight per sheep over the sample period.

Input prices included in the supply specifications include the cost of feedstuff, particularly in the case of the feed intensive industries, as well as other inputs for which the consumer price index is used to proxy their price. Where the relevant information exists, cost of a feed ration for both pigs and broilers is constructed by weighting the domestic prices of the grain and meal components used in the ration. The weights represent the proportion of each feedstuff used in a typical ration in each country. Constructing feed costs in this manner provides a convenient link between grain markets and livestock industries.

For Korea, the partial adjustment supply equations were estimated with a “linear in logs” functional form that yields constant elasticity relationships. For the broiler and egg industries in China, imposing constant supply elasticities would seem inappropriate because both industries have undergone and are continuing to undergo rapid structural change. Consequently, a linear partial adjustment specification was chosen to represent the supply response for the Chinese poultry industry.

A linear partial adjustment specification was also used to represent beef supply in both Australia and Korea, but rather than estimating the parameters econometrically, they were calculated from the supply elasticities estimated in ABARE’s EMABA model (Harris and Shaw 1992). This synthetic approach was taken because estimating a simple partial adjustment specification proved unsuccessful. In the EMABA model, beef supply in both countries is represented by a system of estimated behavioral equations and several beef inventory and production identities. This system of equations appears to be more capable of capturing the complex dynamics of the beef supply response. In the case of Australia, for example, the EMABA model has a small negative beef supply response in the first year. In spite of significant growth in the feedlot industry in recent years, the vast majority of production is still range fed so the short-run response to a price increase is to reduce the slaughter of cows and heifers, and

hence production. The fall in cow beef production outweighs the increase in feedlot output and range fed steer production, and total beef supply initially falls.

In the synthetic partial adjustment framework the beef supply for each period that is estimated in EMABA, even a negative short-run supply response, can be replicated by using an appropriate number of current and lagged price terms. However, since the time path of the response is usually long, it is more sensible to replicate the first four of five years' elasticities and then approximate the time path to the long-run response with the partial adjustment parameter.

The synthetic approach is also adaptable to situations where, as is the case in Australia, there are substitution possibilities in production. Since the substitution is predominantly between wool and beef production in Australia, both current and lagged wool prices are included in the beef supply representation. The impact of the dairy industry on Australian beef production is also captured in a similar manner.

A partial adjustment specification also proved unsatisfactory for estimating Australian chicken supply, so instead it was assumed that poultry supply is perfectly elastic in Australia. With a short production cycle (around four months) compared with other meat industries, poultry producers are capable of adjusting output quickly in response to changes in demand so it is likely that the supply elasticity for this industry is large. Given that it is an annual model, assuming a perfectly elastic response is probably not too unrealistic. Consequently, Australian poultry supply is modeled as a price dependent equation where the retail price is specified as a function of the price of a representative poultry feed ration and other input costs. Poultry net trade is assumed exogenous. Thus, the domestic demand changes alone determine production. While this approach implies an infinite poultry meat supply response, it does incorporate the price of inputs that shift the supply curve when grain prices change.

In contrast, pork supply in China was estimated in a structural model similar to that used in EMABA to model beef supply response. Compared with the simple partial adjustment framework, the structural model approach can incorporate more detailed information about the economic factors as well as the physical and biological constraints that influence pork supply in China. As such it can provide a better means of evaluating the prospects for Chinese pork production. This is particularly important in China's case because it will remain the biggest pork producer in the world (more than 32 mmt in 1994) and relatively small changes in production could have a large impact on feed grain use in the future and, consequently, on world grain markets.

The structural model approach, which was based on the theoretical framework developed by Jarvis (1974), consists of a number of estimated behavioral equations together with both livestock output and inventory identities that ensure the system of equations is closed. The general form of the inventory identities is:

$$K_{ij,t} = K_{ij,t-1} + A_{ij,t} - S_{ij,t} - D_{ij,t} \quad \begin{array}{l} i = \text{livestock type, } j = \text{livestock category} \\ t = \text{time} \end{array}$$

where

$K_{ij,t}$ = livestock inventory of the i^{th} type and j^{th} category at time t

$A_{ij,t}$ = livestock additions/births of the i^{th} type and j^{th} category during period t

$S_{ij,t}$ = livestock slaughter of the i^{th} type and j^{th} category during period t

$D_{ij,t}$ = livestock deaths of the i^{th} type and j^{th} category during period t .

Ideally, the livestock categories would include female breeding stock, adult male or fattening animals, and animals that are less than one year old.

The behavioral equations represent the important decisions of producers, especially those affecting the slaughter or retention of female breeding stock, the most important source of changes in production. Generally, in livestock production the theory of decision making suggests producers are rational if they invest in breeding stock when they expect the net present capital value of these animals to exceed either their current slaughter value or the expected return from some alternative agricultural activity, if one exists. The investment occurs in the form of

increasing the inventory of breeders by reducing the slaughter of the current breeding stock and promoting more replacement breeders.

The model of pork supply in China consists of four behavioral equations, one each for sow inventories, pigs born, total slaughter and slaughter weight, identities for “other pig” and total inventories, and an identity for pork production. Although preferable, sow and “other pig” slaughter decisions were not modeled individually because of data limitations. In the Chinese pork supply model, the sow inventory equation is the most important behavioral equation because it embodies earlier decisions by producers about slaughter and promotions to the sow herd. The specification of the sow inventory equation is:

$$KSOW = f(PPK/CPI, PGN/CPI, KPIG, \text{Time})$$

where

KSOW = inventory of sows

PPK = nominal price of pork

PGN = nominal price of grain

CPI = consumer price index

KPIG = total inventory of pigs.

Initial estimation of this equation with a limited sample of only 14 observations resulted in parameters for the price variables that, according to economic theory, had the incorrect sign. The same result held with reestimation that employed different functional forms and alternative price variables and ratios. As an alternative, the parameters for the price variables were chosen to impose what was considered to be a plausible set of elasticities while the remaining parameters were estimated. Notably, the elasticity on grain prices was expected to be considerably smaller than the own price response. This assessment was based on personal communication with officers of the Chinese Academy of Agricultural Sciences, Ministry of Agriculture who indicated that in backyard pig enterprises, which accounted for 85 percent of pork production in 1995, premixed feeds make up a smaller proportion of total feed intake than in similar operations in developed countries. A linear relationship was also used so the elasticities could vary with sow

inventories and prices, a feature considered desirable given the structural change that is possible in the Chinese pig industry in the future.

A convenient means of summarizing the structural model of the Chinese pig industry and verifying that it is dynamically stable is to estimate the pork supply elasticities associated with the model. Since estimating these elasticities by arithmetic means is not a trivial exercise, they are obtained instead by simulation experiment. The first step in this process is to set all exogenous variables to a constant value and solve the model a sufficient number of periods to generate a long-run equilibrium solution. Achieving a long-run equilibrium verifies the model's dynamic stability. The model is then used in a simulation experiment where each supply price is perturbed permanently by a fixed percentage from its equilibrium value, *ceteris paribus*. The new stable solution is compared with the equilibrium values to yield estimates of the supply response.

The estimates of the supply elasticities associated with both the structural model of pork supply in China and the partial adjustment supply models are presented in Table 1. Notably, the short-run own price beef supply response is small but negative in Australia but is positive in both South Korea and China. An increase in Australian milk prices also has a small negative effect on beef production in the short run, as dairy producers withhold cows from slaughter in response to higher beef prices. However, in the medium and long run the beef supply elasticities for each country are unambiguously positive with respect to its own price and in the case of Australia, the price of milk.

In contrast, the estimated own price supply elasticities for all other meats and eggs are positive, regardless of the length of run and in general, are larger than those of beef. As expected *a priori*, the estimated long-run supply response for poultry meat is the largest among the livestock industries in both South Korea and China. In addition, the pork and poultry supply elasticities in South Korea are bigger than the comparable elasticities for China, probably reflecting the modern and highly commercialized structure of these industries in Korea.

The results also suggest that sheep meat production in China is quite responsive in the long run to a change in its own price but less responsive to the price of wool. On the other hand, the initial impact of a price change is small. This in part reflects the structure of the sheep industry in China, which is oriented more toward wool than toward meat production. In addition,

given a gestation period of five months and the predominance of range feeding of sheep, it is hardly surprising that sheep producers in China do not respond quickly to changes in returns. A similar result is reported for Australia in the EMABA model.

The EMABA model also contains estimates of pork elasticities for Australia and South Korea that are comparable to those reported in this study. For Australia, Harris et al. (1992) report an impact elasticity of 0.05, slightly smaller than in this study, and a long-run response of 0.90 compared with 0.78 reported here. While the estimated own price pork supply elasticity in South Korea is almost identical in both studies in the short run, the long-run elasticity for pork of 4.0 in the present study is somewhat larger than the 3.5 that is reported for the long run by Harris et al. (1992).

Unfortunately, there is a paucity of estimates of supply elasticities for livestock products in China. However, the USDA Economic Research Service (1994) does have a Country Projections and Policy Analysis (CPPA) model for China that contains supply elasticities among its large set of parameters. In the static version of the CPPA model, the pork supply elasticity is 0.5, similar to the impact elasticity of 0.6 estimated in this study but considerably smaller than the long-run response of 1.4. For poultry, sheep meat, and eggs, the CPPA model uses 0.8, 0.3, and 0.8, all of which are considerably larger than the comparable impact elasticity but significantly smaller than the long-run elasticities of 3.7 for poultry and 2.1 for both sheep meat and eggs, that are reported in this analysis. In contrast, the long-run beef supply elasticity of 0.57 estimated in this study is somewhat smaller than the 0.88 employed in the CPPA model for China.

Domestic Demand

A feature of the models is the inclusion of a two-stage budgeting process to represent domestic meat demand in Australia, South Korea, China, and the EU. In the first stage, consumer expenditure for the meat group is modeled as a function of the price of meat, the price of other goods usually represented by the CPI, and real per person consumption expenditure. Seafood was also found to be an important substitute for the meats in South Korea.

In a study that analyzed the differences in income elasticities for meats among a number of countries, Unnevehr (1991) concluded that meat demand increases with economic growth to a maximum when countries reach the middle income stage. As incomes continue to rise meat demand falls. Consequently, for the high-income countries Australia and South Korea and the EU, where it is more reasonable to impose constant elasticities on the demand relationship, a “linear in logs” specification was estimated. In contrast, a linear functional form was used for the meat expenditure equation in China to recognize that average consumer incomes are low there in comparison with other countries. The linear form permits meat consumers’ responsiveness to adjust as prices, income, and the quantities consumed vary through time.

The estimated price and income elasticities for the meat group in each country are presented in Table 2. All own price elasticities and income elasticities have the appropriate sign. As expected a priori, the results indicate that meat consumers in China are more responsive to changes in income and less responsive to a change in the price of meat than are their counterparts in Australia, EU, or South Korea.

In the second stage of the budgeting process, a system of equations is used to allocate total meat expenditure among the various meats included in the group. For Australia and China the expenditure share equations for beef, pork, poultry, and sheep meat were estimated using Deaton and Muellbauer’s (1980) Linear Approximation Almost Ideal Demand System (LA/AIDS). The LA/AIDS system was also used to estimate aggregated EU demand for beef, pork, and poultry. However for South Korea, a Linear Inverse Demand System (LIDS) developed by Moschini and Vissa (1992) and Eales and Unnevehr (1993) was used in the second stage and only beef, pork, and poultry were included in the system.

In contrast to the widely used LA/AIDS system, the inverse demand system assumes that quantities are predetermined by production and prices adjust in the market so the available quantities are consumed. This assumption seemed most appropriate in South Korea where, historically, government policy has been to control consumer price increases by adjusting the quantity of meat supplied to the market. This policy is implemented with the aid of quotas and embargoes on meat trade. When the LA/AIDS model was estimated for South Korea with the same data set it did not work well, further supporting the assumption that meat quantities are

predetermined in that country. For other countries like Australia, it is debatable if an LA/AIDS or LIDS approach is preferable for estimating meat demand. Where trade in a meat commodity is large, as is the case for Australian beef, it is difficult to assume that quantities supplied to the domestic market are predetermined since product can be diverted from export markets when domestic beef demand rises.

To accord with theory, both the homogeneity and symmetry restrictions were imposed on the parameter estimates in every demand system. With the exception of China, a fairly straightforward form of dynamic consumer behavior was also incorporated in each country's meat demand system. Short-run inventory adjustments, habit persistence, and price stickiness have all been posited as factors that may result in significant dynamic behavior by consumers. Data limitations prevented the inclusion of dynamics in the Chinese meat demand system.

The framework used to represent such dynamic behavior was the partial adjustment demand system developed by Ball, Beare, and Harris (1989). When applied to the LA/AIDS model, it results in expenditure share equations of the form

$$W_{i,t} = (1 - D) \left\{ A_i + \sum_j (B_{i,j} * \ln(P_{j,t}) + C_i * \ln(\frac{Y_t}{PM_t})) \right\} \\ + D \left\{ \frac{P_{i,t} * Q_{i,t-1}}{\sum_i P_{i,g} * G_{i,t-1}} \right\} \quad i, j = 1 \dots, n$$

where

$W_{i,t}$ = the expenditure share of the i^{th} meat in period t ,

$P_{i,t}$ = the price of the i^{th} meat in period t ,

$Q^{i,t}$ = the quantity consumed of the i^{th} meat in period t ,

Y_t = total meat expenditure in period t ,

PM_t = the Stone's meat price index in period t , and

D = the partial adjustment parameter.

There are a number of features of this model that make it very appealing for structural model applications. All the restrictions implied by theory, homogeneity, symmetry, and adding-up can be imposed in each period of the adjustment as well as in the long run, so it is easy to estimate and is parsimonious in parameters. Although the adjustment path is constrained to be identical for all the meats, it is easy to retrieve the estimated elasticities in each time period from the partial adjustment demand system. For analysts who use large structural models to evaluate policy simulation, elasticities are the most important parameters in understanding and explaining the estimated impacts of policy change. Another feature of the model is that the estimated parameters, and hence the elasticities, are invariant to which equation is deleted from the system in estimation.

It should be noted that the partial adjustment demand system used here differs from the partial adjustment model that is nested within the Flexible Demand System reported by Anderson and Blundell (1983) and that has been used more frequently in applied demand analysis; see, for example, Kesavan et al. (1993). In estimating the Flexible Demand System, the restrictions from theory typically are imposed only on the long-run behavior. These theoretical restrictions are derived from the assumption that consumer preferences, and hence demand equations, are well behaved. In regard to short run demand equations contained within a dynamic demand system, Phlips (1983, p 186) states that “in each period, the current (or instantaneous) utility function is maximized as if it were a static function, without consideration of future changes. Given the current values of the taste change parameters, the general restrictions have to show up again.” If, for instance, the homogeneity restriction is relaxed over the adjustment path, then among other things, consumers can behave in the shorter run as if there were money illusion. Similarly, if the demand system is not additive then the sum of projected expenditures on each meat in any period will not necessarily equal total meat expenditure in the same period. A demand system that relaxes such restrictions could be troublesome to the credibility of a structural model like FAPRI, which normally is used for short- and medium-run policy analysis.

In addition to the meat demand system, the EU and China models also include a single equation representation of sheep meat and egg demand, both of which are represented as a function of their deflated own price and real per person income. A “linear in logs” functional form was estimated because it is not unreasonable to assume that the consumption of both has reached a “mature” stage in their respective countries. In China, for example, at an estimated 235 eggs per person in 1994, consumption is among the highest in the world.

The estimated price and scale flexibilities for South Korea are presented in Table 3. The demand for all three meats in South Korea is inflexible, suggesting that a 1 percent increase in quantity consumed is associated with a less than 1 percent fall in normalized prices. The negative sign on every cross price flexibility suggests that beef, pork, and poultry are also gross q-substitutes. Furthermore, the negative estimated scale flexibilities indicate that as the scale of consumption increases, the marginal value of meats in consumption declines. In terms of the dynamics, the rate of adjustment is quite fast, as is to be expected a priori with meat demand, with 60 percent of the adjustment occurring initially and 84 percent after two years. Although not reported, the Antonelli substitution matrix computed at the sample means is negative semidefinite, suggesting that the distance function is an acceptable characterization of consumers’ preferences for meat in South Korea.

To the authors’ knowledge there are no other reported estimates of meat flexibilities for South Korea. However, there are numerous studies reporting estimates of meat demand elasticities in South Korea, so to facilitate comparison, the implicit “conditional” long-run elasticities were derived from the flexibility estimates. They are presented in Table 4 while the estimates of price and income elasticities for Australia, China, and the EU, are reported in Tables 5, 6, and 7. It should be noted that for the Australian, Chinese, and EU meat demand systems, the Slutsky substitution matrices derived at the sample means all appear to satisfy the regularity conditions. All eigenvalues were negatively signed with the exception of the dominant eigenvalue in the Slutsky matrix for China, which had a value of 0.00361. However, in the absence of estimating the associated standard errors, which is beyond the scope of this research, no statistical inference can be made about the regularity conditions. Nevertheless, the negativity

results do suggest that the estimated demand systems are likely to be underpinned by “well-behaved” consumer preferences.

The estimated own price elasticities for the meats are all appropriately signed and in general are more elastic in South Korea than in the other countries. This is not an unusual result for inverse demand systems; see, for example, Eales (1994). Overall, Chinese meat consumers are the least responsive in the long run to changes in the own price of meat, although with the exception of pork, the price elasticities in the EU are also estimated to be inelastic. In contrast, expenditure elasticities in China are nearly twice the size of those estimated for the other countries. For beef, poultry, and sheep meat, which among them accounted for only 22 percent of total meat expenditure on average in China from 1986 to 1992, it is estimated that every 1 percent increase in expenditure results in a 2 percent rise in consumption. However, with expenditure elasticities estimated to exceed one in the long run, the consumption of beef, poultry, and sheep meat in Australia, beef and pork in South Korea, and pork consumption in the EU are still quite responsive to a change in meat expenditure. In contrast, the expenditure elasticities for pork in Australia and poultry in the EU are small.

The estimates of compensated meat demand elasticities suggest that in general, the meats are net substitutes, although the results vary considerably among the represented countries. South Korea is the only country in which the meats (beef, pork, and poultry) are all substitutes. In Australia and China, beef and sheep meat are significant substitutes while pork and sheep meat and poultry and sheep meat could be complements, although probably not strong complements, in Australia and China. On the other hand, the estimated compensated demand elasticities for the EU suggest that both beef and poultry are strong substitutes with pork, but could complement each other.

EU meat consumers also appear persistent in their consumption habits, with around only 33 percent of their long-run response to a change in prices and expenditure completed after one year and less than 60 percent by the second year. This contrasts with Australian meat consumers, who are estimated to complete 83 percent of their adjustment within one year and to be almost at their long-run equilibrium consumption levels after two years.

Examination of similar elasticities presented in other studies indicates that there is little consensus about the magnitude of both own price and expenditure elasticities as well as the sign and magnitude of cross price elasticities. This is not a surprising result given the variation in the approaches taken to estimate these elasticities, the use of different data, and that consumer behavior is assumed, in general, to be static. In a study of meat demand in Pacific Rim countries using a Rotterdam model with the usual restrictions from theory, Capps et al. (1994) report, for South Korea, inelastic own price responses that range in magnitude from -0.47 for chicken to -0.94 for beef. While these are sharply lower than comparable elasticities in the present study, the estimates of expenditure elasticities in both studies are more similar. Capps et al. estimate expenditure elasticities of 1.29, 0.83, and 0.78 for beef, pork, and chicken compared with 1.31, 0.99, and 0.36 for the same meats in this study. Other studies by Shin (1994), Harris et al. (1992), and Hayes, Ahn, and Baumel (1991) also reported inelastic own price elasticities for meat demand and similar estimates of expenditure elasticities in South Korea. Generally, beef has the largest expenditure elasticity while poultry has the smallest.

For Australia, Harris et al. (1992) report own price elasticities for beef, lamb, mutton and poultry of -0.92, -1.20, -2.31, and, -0.79, comparable to the estimate of -1.51 for beef, -1.96 for sheep meat, and -0.78 for poultry reported in this study. The pig meat elasticities, however, are quite different, with a relatively inelastic estimate of the own price demand response of about -0.48 in the present study, compared with -1.39 for pork, and -0.73 for bacon and ham in the EMABA model. With the exception of pig meat, income elasticities for the meats are considerably smaller in EMABA than comparable estimates in this report.

In contrast to this analysis, other studies that have reported estimates of meat demand elasticities in China typically have utilized household survey data in their analyses, so the results are not strictly comparable. Wang, Halbrendt, and Johnson (1995) used an LA/AIDS paradigm with urban household survey data for 1986 to 1991, to estimate the demand for a number of animal products in China. They reported own price demand elasticities for beef and mutton, and pork of -0.67 and -0.85, very similar to the estimate of -0.71 obtained for both in this analysis. On the other hand, the own price elasticity for poultry varies considerably between the two

studies, with Wang et al. estimating an elastic poultry demand of -1.33 compared with -0.75 in the present study.

There is an even larger divergence between analyses in the magnitude of the expenditure elasticities for beef and mutton, and poultry. In this study, beef, sheep meat, and poultry all have expenditure elasticities around 2.0, suggesting they are important luxuries among the meats. While Wang et al. also find poultry a luxury, their results indicate that beef and mutton are necessities. However, both studies agree that pork is a necessity in China.

Using the same urban survey data, albeit for an earlier period, Chern and Wang (1994) used a Linear Expenditure System (LES) to estimate that both beef and pork demand are price inelastic in China while poultry is very price sensitive with an elasticity of -1.82. However, compared with the Wang et al. study, Chern et. al. reported relatively large expenditure elasticities of 3.01 and 1.45 for poultry and pork. The result suggests that pork is also a luxury in China, which seems implausible given that on average it accounted for just under 80 percent of all meat expenditure between 1986 and 1992.

Estimates of meat demand elasticities in rural areas compiled from household survey data, in general lend support to the magnitude of the elasticities reported in the present analysis. Fan, Wailes, and Cramer (1995) used an LA/AIDS model and data from rural household surveys covering the period 1982 to 1990, to estimate demand for seven major food groups, including meat. They estimated a conditional own price meat demand elasticity of -0.38 and an expenditure elasticity of 1.27. In general, the elasticities presented in Table 6 lie between the estimates reported in other studies for urban and rural consumers in China.

To provide additional evidence about the magnitude of the expenditure elasticities, an LES model was also estimated with the same data set used to generate the elasticities in Table 6. The estimates of expenditure elasticities obtained from the LES were 0.76 for pork, 1.48 for sheep meat, 1.91 for poultry, and 2.14 for beef. With the possible exception of sheep meat, the estimates of expenditure elasticities from both models are not significantly different.

There is a dearth of estimates of meat demand elasticities for the EU. However, in a recent study Hayes and Canali (1990) analyzed the demand for meat in individual member states of the EU as well as the EU as a whole. Employing a static LA/AIDS to model the demand for

beef, pork, poultry, and sheep meat, Hayes et al. used pooled time-series and cross-section data with intercept shifters for each country represented in the model. For the EU they report inelastic own price wholesale demand elasticities for all the meats, ranging from -0.47 for poultry, the most price inelastic, to -0.87 for pork. In the present study, the short-run own price elasticities for all meats are also small, but in the long run the estimate of the own price demand elasticity for pork is -1.39. While the estimates of expenditure elasticities for beef and pork are almost identical in both analyses, Hayes et al. report an expenditure elasticity of 1.21 for poultry demand in the EU, more than twice the 0.61 estimated in this study. The own price and expenditure elasticities for sheep meat are estimated to be -0.30 and 0.45 (not reported in the tables), indicating that sheep meat demand is inelastic and is a necessary meat in the EU. This result is supported by Hayes et al.

Generally, the models use simple price transmission equations to link the farm, wholesale, and retail levels. The price transmission equations are estimated with a ‘linear in logs’ functional form. Although they are not reported, in all cases, a 1 percent change in the farm level price has a relatively smaller impact on consumer demand as it is associated with a less than 1 percent price change at the retail level.

Trade

The trade equations in the models provide the important link between each country’s domestic market and the rest of the world. Specifically, the models contain behavioral representations of Australian beef export demand, import demand for beef, pork, and poultry in South Korea, and for China, both pork and egg export demand as well as import and export demand for poultry. All other trade flows are exogenous in the models either because they have been insignificant historically or because like sheep meat, they only receive minimal coverage in the suite of FAPRI models. However, regardless of whether the trade flows are modeled behaviorally or not, they all appear in the market clearing identities, the equations that simultaneously determine the domestic market price of the meats in each country and the price of eggs in China.

Unlike the detailed structural depiction of domestic demand, trade relationships in the models typically are represented by simple single equations in which import and export demand are determined by the relative movement of the domestic price of each meat, and the price of the competing traded product. The traded product or “world” prices are adjusted explicitly in each equation for exchange rate movements and where applicable, tariffs and other duties. For the models reported here, U.S. farm prices of beef, pork, and poultry are used as proxies for the price of all the internationally traded meat products. It should be noted that since every foreign meat trade flow is linked to the market clearing identities for that particular meat in the U.S. component of the FAPRI livestock model, a change in the trade position for any country will simultaneously affect both the “world” or U.S. price and the domestic meat price in other countries.

While most of the parameters in the trade equations are estimated using OLS regression, in some instances synthetic behavioral equations, in which elasticities are simply imposed on the data, are used to represent trade demands. Typically, the latter approach was adopted when data limitations prevented estimation of the parameters, when estimation produced implausible and unacceptable elasticities, or because recent changes in government policy or market structure made it inappropriate to use regression estimates.

In South Korea, for example, historically the trade in meat products has been strictly controlled by government policy in an effort to support domestic livestock producers. A combination of import bans, tariffs, and nontariff barriers like shelf-life restrictions, have led to minimal imports of pork and poultry. In fact, there were effectively no pork or poultry imports before 1990 and by 1994 shipments had reached only 25,000 tons carcass weight. Under the recent GATT outcome, however, South Korea has already begun to liberalize its trade in pork and poultry and by the middle of 1997, although imports of both meats will still be subject to tariffs, there will be no quantitative restrictions for either meat.

Similarly, the South Korean government has maintained a system of quotas, tariffs, and wholesale mark-ups to control beef imports even though recently larger volumes of beef have been imported. However, as a result of the GATT round, South Korea will increase substantially

its minimum access levels for beef imports until 2001, after which time beef imports will be subject to a tariff alone.

In light of the data limitations and recent changes in South Korea's meat import policy, there was no attempt to estimate the parameters for the meat import demand equations. Instead, import demand elasticities for beef, pork, and poultry are imposed in synthetic equations in the South Korean model. The functional form used is first difference in logarithms while the elasticities, which are based on comparable parameters estimated by Harris et al. (1992) for Japan, were fixed at -1.0 for beef, -0.66 for pork and -1.4 for poultry.

Although growing in more recent years, the volume of meat traded by China still remains small despite a doubling of pork consumption, a sixfold increase in poultry consumption and a tenfold rise in beef consumption over the last decade. As in South Korea, both government policy affecting the import and export of meat, and data limitations, influenced the approach to modeling trade flows in China, albeit in a slightly different way. Given that the central government in China utilizes trade as a measure to attempt to control food price inflation, the poultry import equation and both the poultry and egg export equations in China were specified as a function of the relevant domestic retail poultry or egg price relative to the consumer price index. Consequently, when domestic poultry prices rise faster than inflation, imports rise and export volumes fall and price inflation is mitigated. Similarly, egg exports fall when retail egg prices rise relatively faster than inflation and partly offset the initial increase in egg prices.

While the estimated elasticities for the poultry and egg export equations were satisfactory, initial estimation of the poultry import equation with a sample of only five observations produced an incorrectly signed parameter for the price variable. To overcome this problem, an own price import demand elasticity of -1.1 is imposed in this equation.

Also, it is worth noting that when meat and egg trade demands in China were specified as a function of domestic and "world" prices, the parameters were generally incorrectly signed and the equations did not explain historical trade patterns at all well. The one exception though is Chinese pork export demand, which when specified as a function of the domestic price and the

exchange rate adjusted, U.S. pork price, produced an elasticity estimate which is correctly signed and of plausible magnitude, even though the equation “fit” is poor.

It also should be noted that the estimates of Chinese import and export demand elasticities are unlikely to be robust because of the small sample size used in estimation and because government policy as it affects trade in meat is likely to change as China attempts to meet its APEC commitment. Nevertheless, the underlying elasticity estimates all appear plausible in magnitude and seem preferable to the alternative of simply imposing elasticities in the absence of estimates from other studies.

The South Korean model also contains a set of it-then conditional statements that endogenously determine if the commitments of the GATT outcome are satisfied. This ensures that south Korea imports of beef, pork, and poultry, at least meet the minimum import levels agreed to under the GATT. If “world” prices fall and imports become relatively cheaper than domestic product, imports can exceed the GATT minimum.

Estimated and imposed import and export demand elasticities for each country are presented in Table 8. There are very few similar estimates reported in the literature. Harris et al. (1992) report a short-run beef export demand elasticity for Australia of -0.64, comparable to the elasticity of -0.6 estimated in this study. However, Harris et al. estimate the long-run beef export demand elasticity to be -1.25, more than twice the size of the elasticity reported here. The authors are unaware of published estimates of import or export demand elasticities for the meats or eggs for either South Korea or China.

An Application of the China Model: An Increase in the Price of Feed Grains

The models documented in this study are used to support FAPRI’s short- and medium-term commodity projection exercise as well as its analyses of U.S. and international agricultural policies. In recent years China has emerged as an important prospective market for U.S. agricultural commodities, particularly feed grains. This reflects growing demand for feed grains in China as meat producers strive to increase output to meet consumers' rising demand for meat. In spite of the central government’s efforts in 1995 to restrain the rapidly rising price of corn by

increasing imports, domestic prices rose to record highs. The likely impacts of a rise in feed grain prices is the subject of the analysis that follows.

To analyze feed grain price increases, a baseline projection was generated for the 10-year period 1996-2004 and used for comparison with the alternative simulation in which grain prices increase by 10 percent above their baseline level. A number of key assumptions were imposed on the model in generating the baseline, the more important of which are presented in Table 9. Significantly, real GDP growth is assumed to fall from 9.2 percent in 1995 to 7.9 percent by 2004. However, at this level, real income growth in China is still expected to be significantly higher than in developed countries and other developing countries over the same period. Crop prices are assumed to rise in nominal terms over the projection period, albeit at a rate less than inflation.

The baseline projections are presented in Table 10. Given that consumer income continues to grow strongly, the demand for meat in China is expected to increase significantly over the projection period. By 2004, meat consumption is projected to reach 61.5 kg per person, 49 percent more than the 41.4 kg per person expected to be consumed in 1995. Pork remains the major meat but its share of total meat consumption falls from an estimated 72 percent in 1995 to just over 60 percent by 2004. Among the other meats, beef and sheep meat consumption per person more than double between 1995 and 2004, while poultry consumption increases more than 80 percent over the same period. In contrast, egg consumption is expected to rise by just under 2 percent to 237 eggs per person. The relatively small increase in consumption reflects both the relatively low income demand elasticity and the already high level of egg consumption in China compared with other countries.

All meat and egg prices rise steadily between 1995 and 2004, reflecting the increase in demand. The prices of beef, pork, sheep meat, and eggs more than double over the projection period. Compared with the other meats, however, poultry prices increase relatively less, largely reflecting the responsiveness of poultry producers to higher prices.

In response to higher prices, the production of eggs and meats expand throughout the projection. Between 1995 and 2004, poultry production doubles to just over 15 mmt, while beef and sheep meat production more than double. In addition, pork production expands from an

estimated 37 mmt in 1995 to 52 mmt by the end of the projection, an increase of 15 mmt or 40 percent. Egg production, however, increases more modestly to 16 mmt by 2004, a 13 percent rise in production in 1995.

Higher domestic demand in China also results in a diversion of pork away from the export market with the volume of pork exported forecast to fall to around 170,000 t by 2004, 15 percent below 1995 estimated exports. Poultry products trade is also expected to rise steadily over the projection period and China is likely to remain a net importer. By the end of the projection period, net poultry imports are expected to reach nearly 300,000 t, compared with about 70,000 t in 1995. Exports should comprise mainly the higher valued cuts while chicken tips and paws are likely to continue to account for the majority of imports.

In the context of the current high grain prices in China, there is some interest in assessing the impact of continuing high prices on China's meat industry. To examine the likely effects, a simulation experiment was conducted in which Chinese grain prices were raised permanently by 10 percent above the baseline level. The results of this experiment appear in Table 11 and Table 12 where they are expressed as percentage differences from the baseline projection.

As a result of higher grain prices, egg and meat prices rise. In particular, the prices of those livestock products that use more feed grains—pork, poultry and eggs—increase relatively more than beef and sheep meat, which are predominantly range fed. By 2004, the prices of pork, poultry, and eggs are as much as 6 to 8 percent higher than in the baseline, compared with 1.5 to 2 percent for sheep meat and beef.

The relatively higher prices for the fed products is due to lower pork, poultry, and egg production as producers respond to higher grain prices by reducing the pig herd and the poultry flocks. Compared with the baseline, after one year the sow inventory contracts 1 percent to 35.9 million head, while the number of pigs born, pigs slaughtered, and the total herd also fall. By the end of the simulation period the pig inventory is 5 million head below the baseline level while pork production falls by 600,000 t, slightly more than 1 percent. By 2004, poultry and egg production fall by between 2 and 3 percent below their baseline level as a result of the higher grain prices.

In contrast, beef and sheep meat production rise in comparison with the baseline, as producers respond to improved returns for both meats. The improved returns are underpinned by an increase in the demand for beef and sheep meat that results from the higher prices of the competing meats, pork and poultry. Consequently, by 2004 the consumption of beef and sheep meat per person increases by more than 1 and 2 percent as compared with the baseline.

The increase in beef and sheep meat consumption is at the expense of pork and poultry, the consumption of which, relative to their baseline level, falls by between 1 and 1.5 percent by 2004. Notably, the total meat consumption per person also falls as a result of the higher grain prices, with the larger beef and sheep meat consumption more than offset by reduced pork and poultry consumption.

The higher pork and poultry prices in China also result in product being diverted away from exports to the domestic market and in an increase in import demand for poultry. As a result, poultry imports increase significantly and net imports of poultry rise by 100,000 t or 35 percent above the baseline level.

Future Model Development

There are a number of possible directions that such development work on the models could take. One area that warrants further analysis is the meat supply components of the models. Compared with demand, the meat supply components in this study have little structure, with the possible exception of pork production in China. The current FAPRI livestock models for EU and Japan have detailed supply structure with explicit modeling of animal inventory changes, births and deaths, slaughter, and meat production. Future work could be undertaken to model beef, pork, and sheep meat supply in particular, in a similar fashion. Tractability of inventory changes is on one hand essential for appropriate feed demand assessment, and on the other hand provides the necessary consistency in meat production that is governed by various biological constraints.

Further analysis of meat and egg demand in China also seems necessary as more data points become available. The LA/AIDS demand system reported in this study is estimated with a much smaller sample than is ideal and the implied elasticities could change markedly if estimated with a larger sample. Testing with the LIDS model could also be worthwhile and modeling urban

and rural demand separately is also desirable given the large differences in income and tastes between these segments of the Chinese population.

The final area for possible future development is the representation of trade. Currently, the models treat meat as a homogeneous product in trade. At some stage a differentiated approach to modeling trade flows could be appropriate. It is well accepted that beef trade in the Pacific Rim has been differentiated for many years (see Harris et al. 1992, for example), and it is only too apparent that international trade in pork and poultry is also characterized by differentiated products, particularly as the trade in these products has become more oriented toward large volumes of individual cuts.

Chinese demand for imported meat products, for instance, appears to be concentrated on the lower valued products like chicken wing tips and paws, as well as pork and beef offal and variety meats. On the other hand, Chinese meat exports to predominantly high-income Asian countries, mostly comprise the high-valued cuts like boned and bone-in chicken legs. The likely continued expansion of the trade in meat cuts will necessitate the representation of meat trade to be re-assessed at some future stage. Nevertheless, the models described in this paper do provide a useful starting point for future development in any of these areas.

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